# Maximizing benefit of solar energy in greenhouses; by greenhouse coverings

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Wageningen UR Greenhouse Horticulture




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# General

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# Requirements of the cover

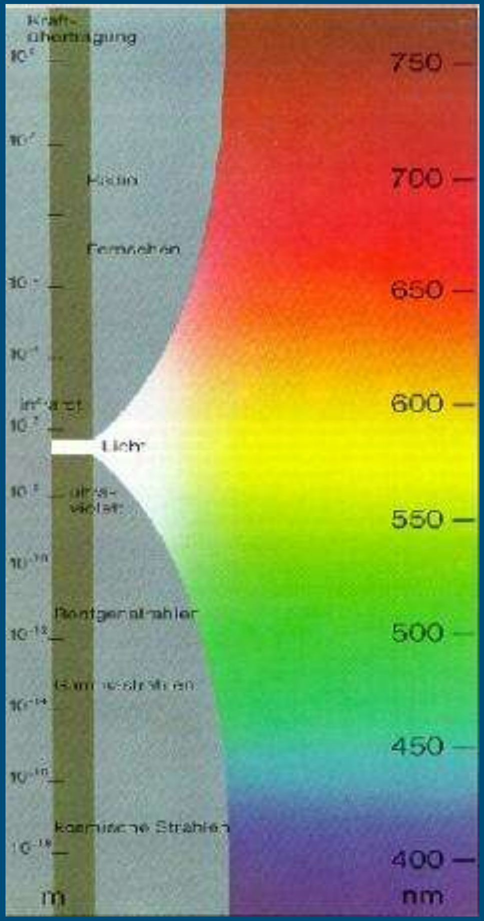
- Covering materials for horticultural applications:
  - High light transmission
  - Optimum light spectrum
  - Optimum heat input - low heat losses
  - Optimum condensation behaviour
  - High mechanical resistance
  - Low sensitivity to ageing (UV, temperatures, chemicals)
  - Fabrication sizes
  - Costs

# General

Solar radiation (300-2500nm),
energy input greenhouse

## Relevant for horticultural applications

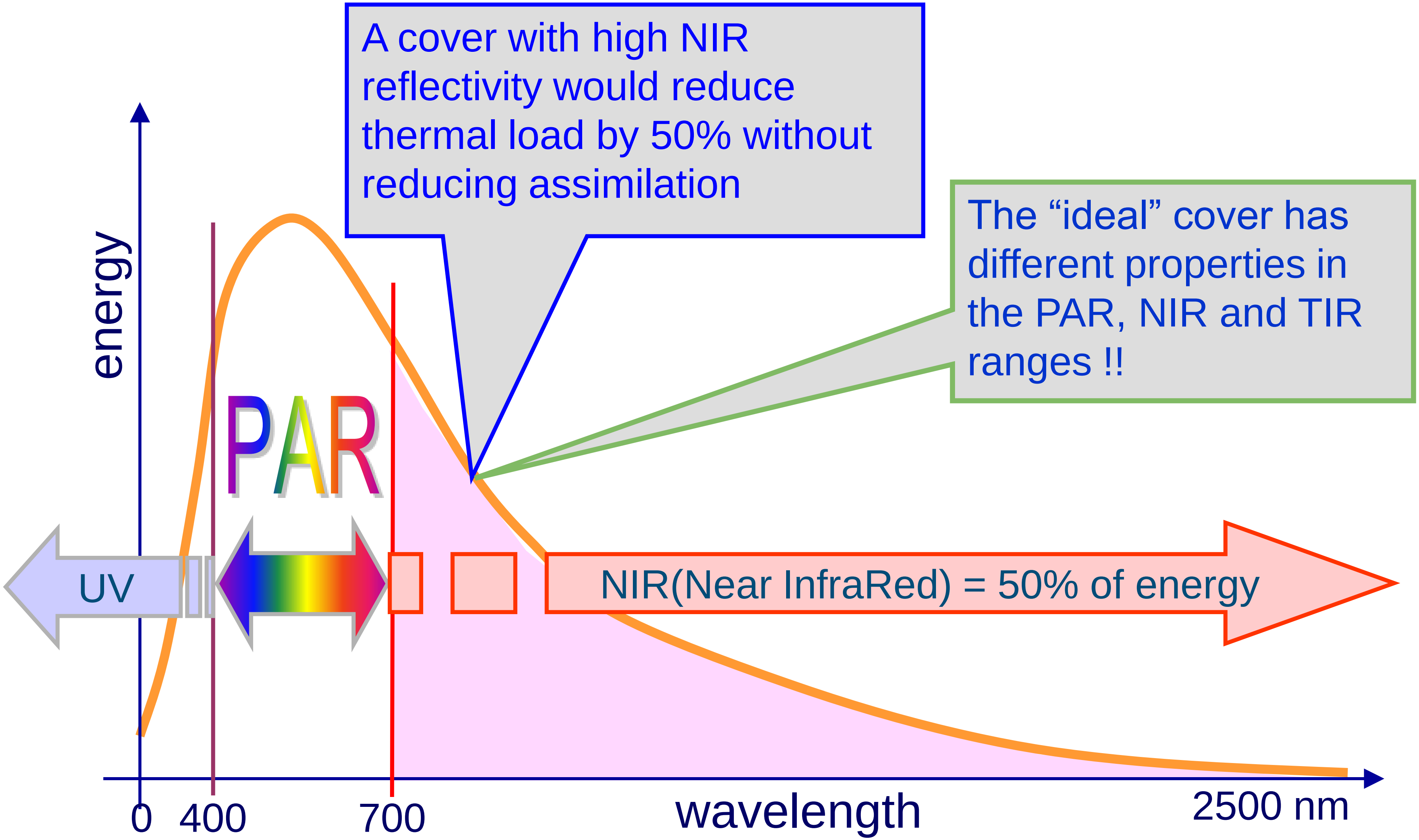
| | | |
|---|---|---|
| **UV** | 300-400 nm | morphogenesis |
| **PAR** | 400-700 nm | photosynthesis, morphogensis |
| **FR** | 700-800 nm | morphogenesis |
| **NIR** | 800-2500 nm | *increasing greenhouse temperature* |
| **FIR** | 2.5-100 µm | *heat radiation* |




Philips

Heat radiation,
energy loss greenhouse

# Radiative properties of the cover

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# Problem: High temperatures in temperate regions

- Cutting-off the NIR component of sun radiation might help.
- NIR can be excluded by reflection or absorption.
  - Absorption by nano particles → surface-plasmon resonant
  - Reflection by interference
- The effect of NIR absorbers on greenhouse climate was calculated with a simulation model and tested in Spain Almeria.
- The effect of NIR reflection on greenhouse climate was calculated with a simulation model and tested in the Netherlands (Bleiswijk).

# Light quantity

# Light quantity

Light transmission <<50%

In winter light is limiting factor

Tropics

Spain

# Light quantity

Light transmission >75%

In winter light is limiting factor

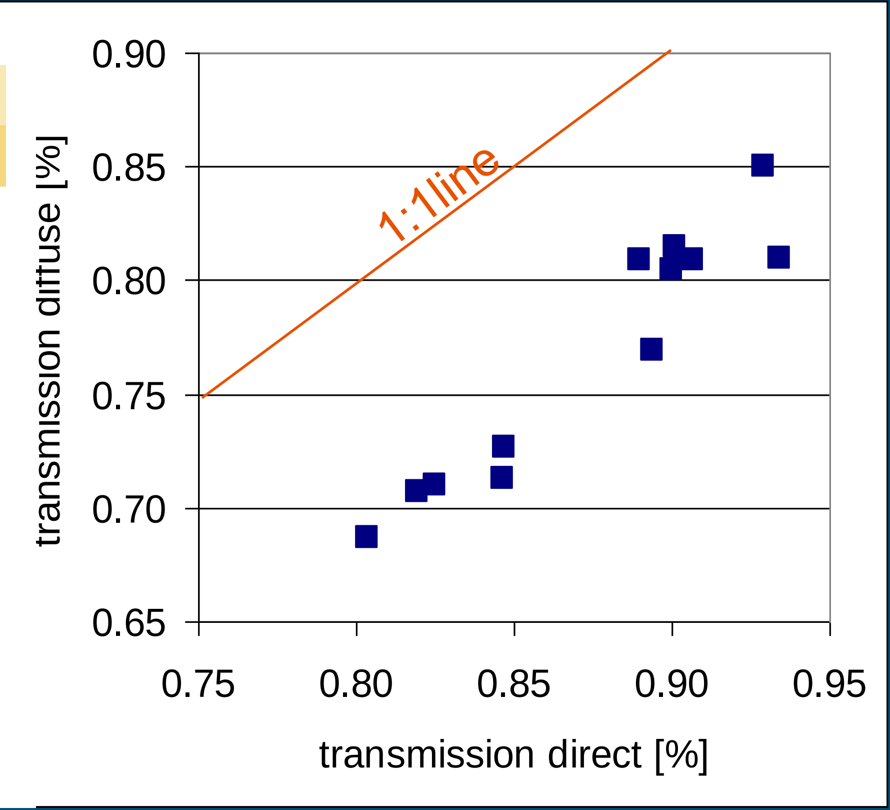
The Netherlands

Spain

# Light quantity

- PAR transmission different materials

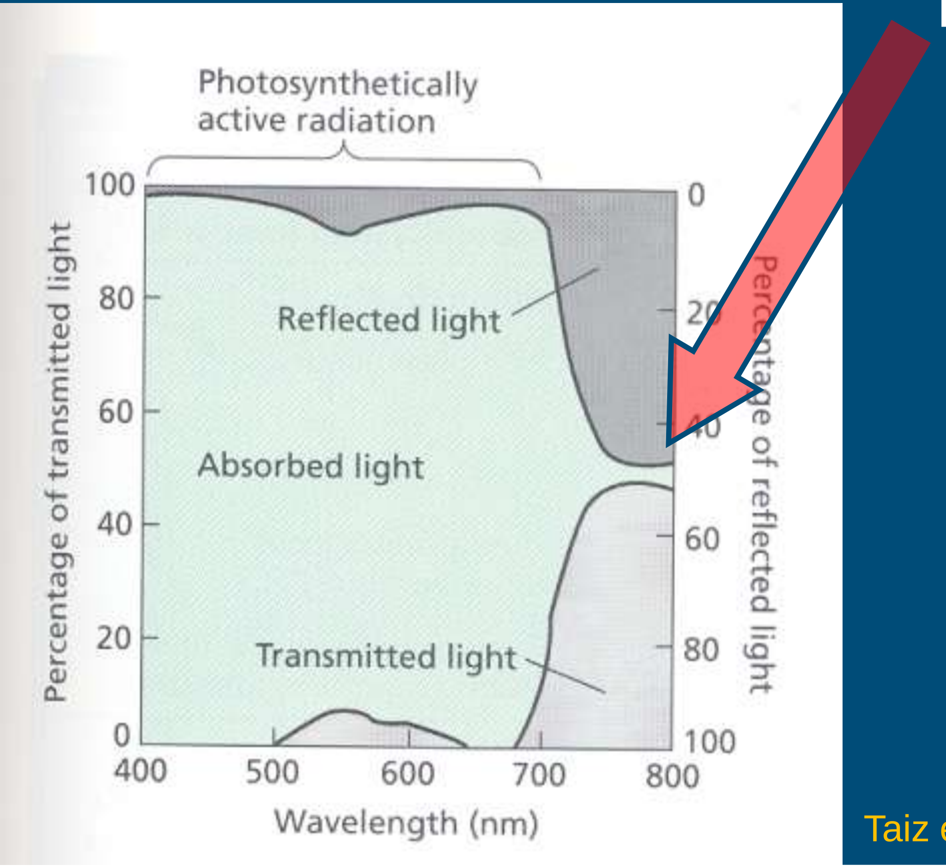
| ***Material*** | ***perpendicular*** | ***diffuse*** |
|---|---|---|
| FVG PE-EVA-film Sun Eva 5 Plus | 89.0% | 80.9% |
| FVG PE-EVA film Sun Saver 5 Pro | 89.4% | 76.9% |
| FVG PE-film FVG Kupfer 5.10 | 82.0% | 70.7% |
| Plastika Kritis PE-EVA-film TUV 3946 | 90.1% | 81.5% |
| Plastika Kritis PE-EVA-film TUV 3945 | 84.7% | 72.6% |
| Plastika Kritis PE-EVA-film TUV 3999 | 84.7% | 71.3% |
| Plastika Kritis PE-EVA-film TUV 3973 | 80.3% | 68.7% |
| Plastika Kritis PE-film UV 2794 | 90.0% | 80.5% |
| Pati EVA-film Patilite E | 82.5% | 71.0% |
| Pati EVA-film Patilux LD | 90.6% | 80.9% |
| Asahi ETFE Film F-Clean Clear | 92.9% | 85.0% |
| Asahi ETFE Film F-Clean Diffuse | 93.4% | 81.0% |



# Light quality

# Light quality

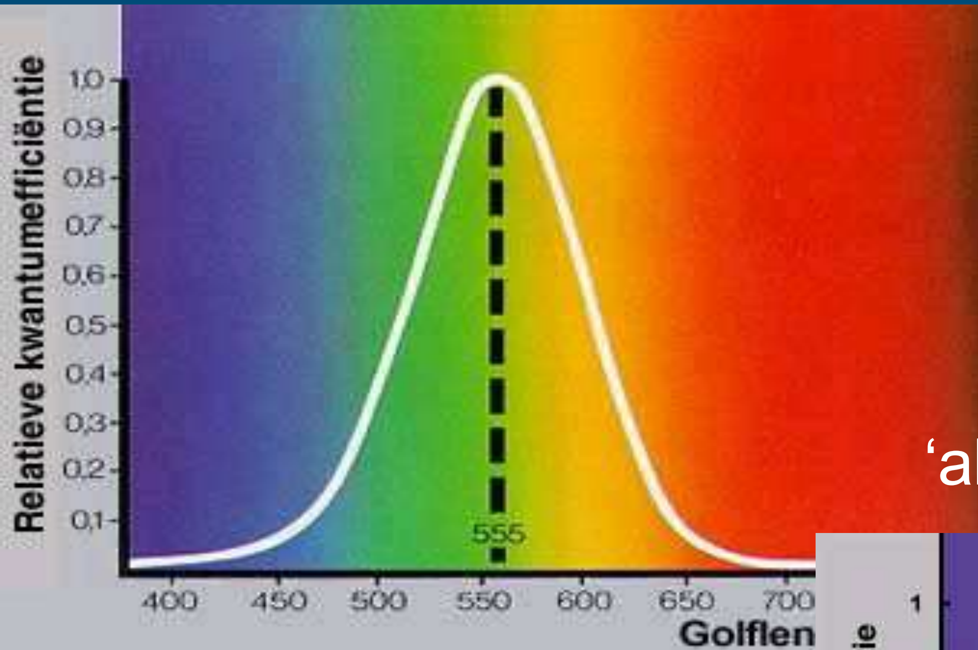
- Absorption, reflection, transmission by a leaf




Plant helps by reflecting NIR

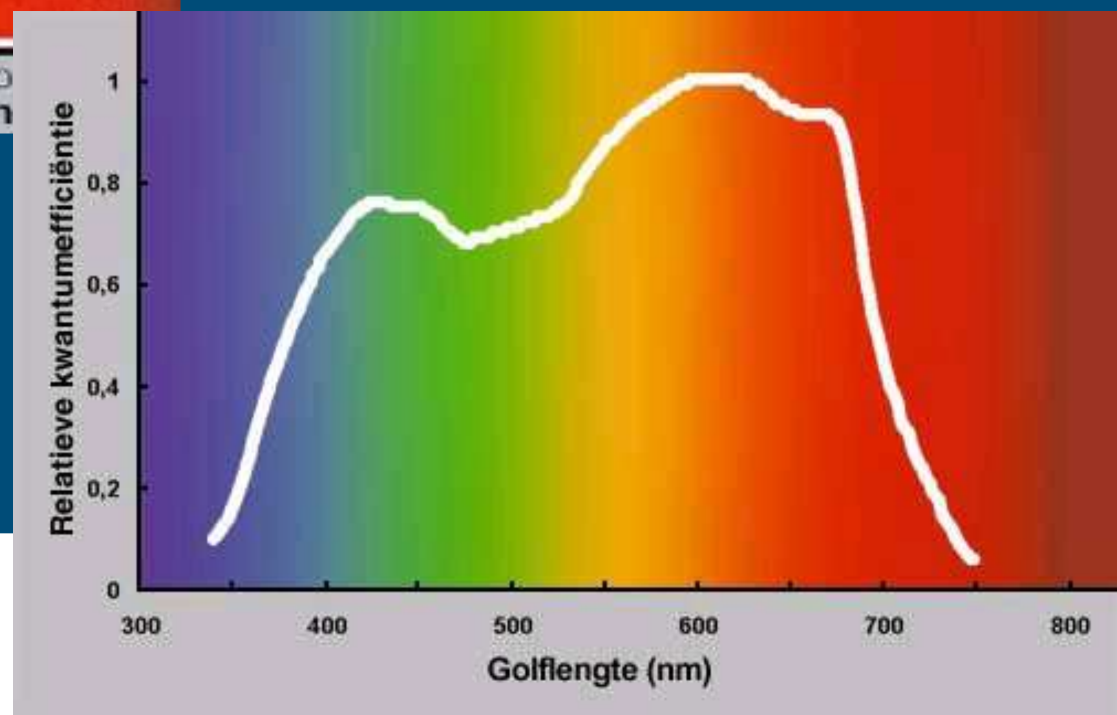
Taiz en Zeiger, 1998

# Photosynthesis

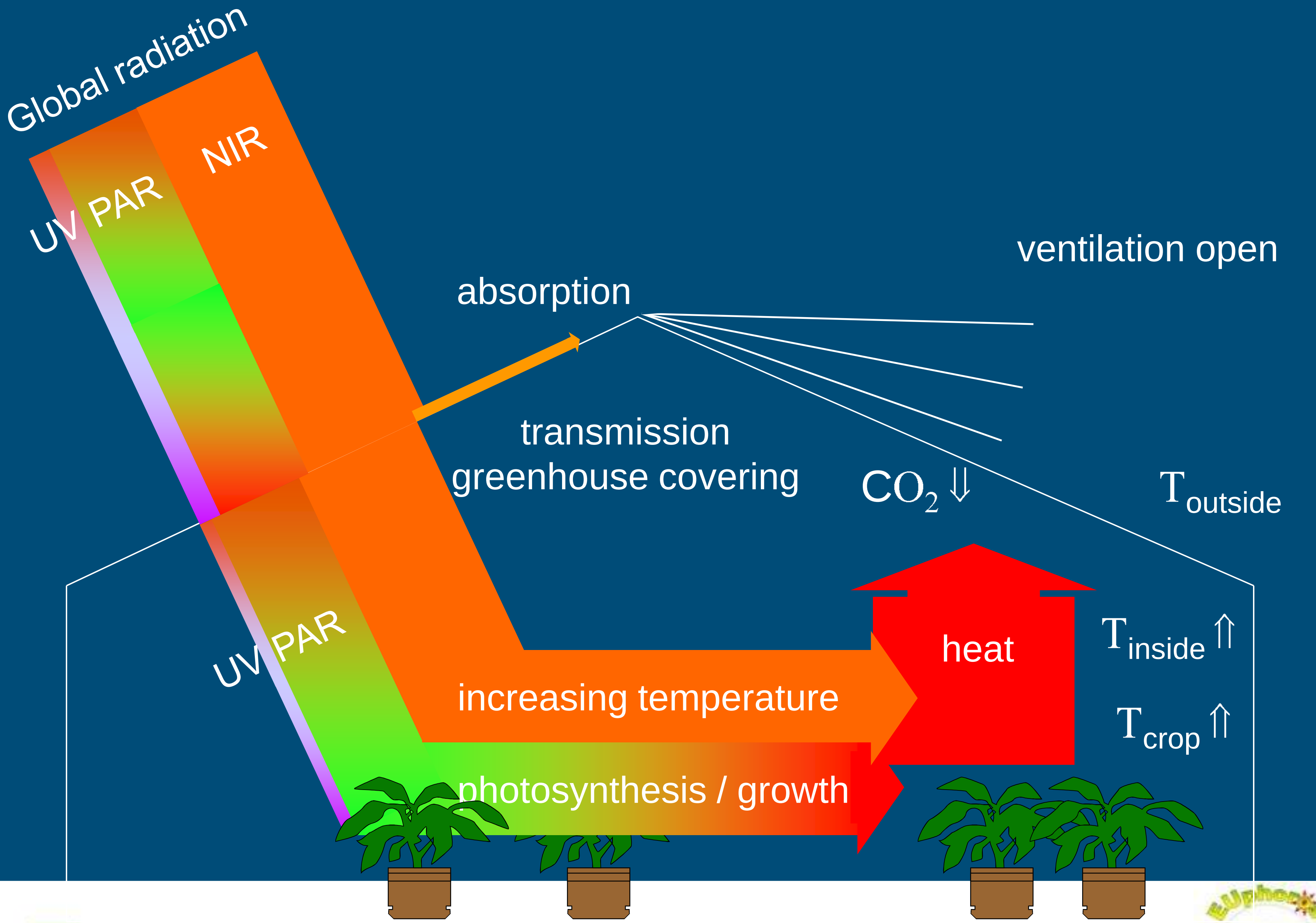


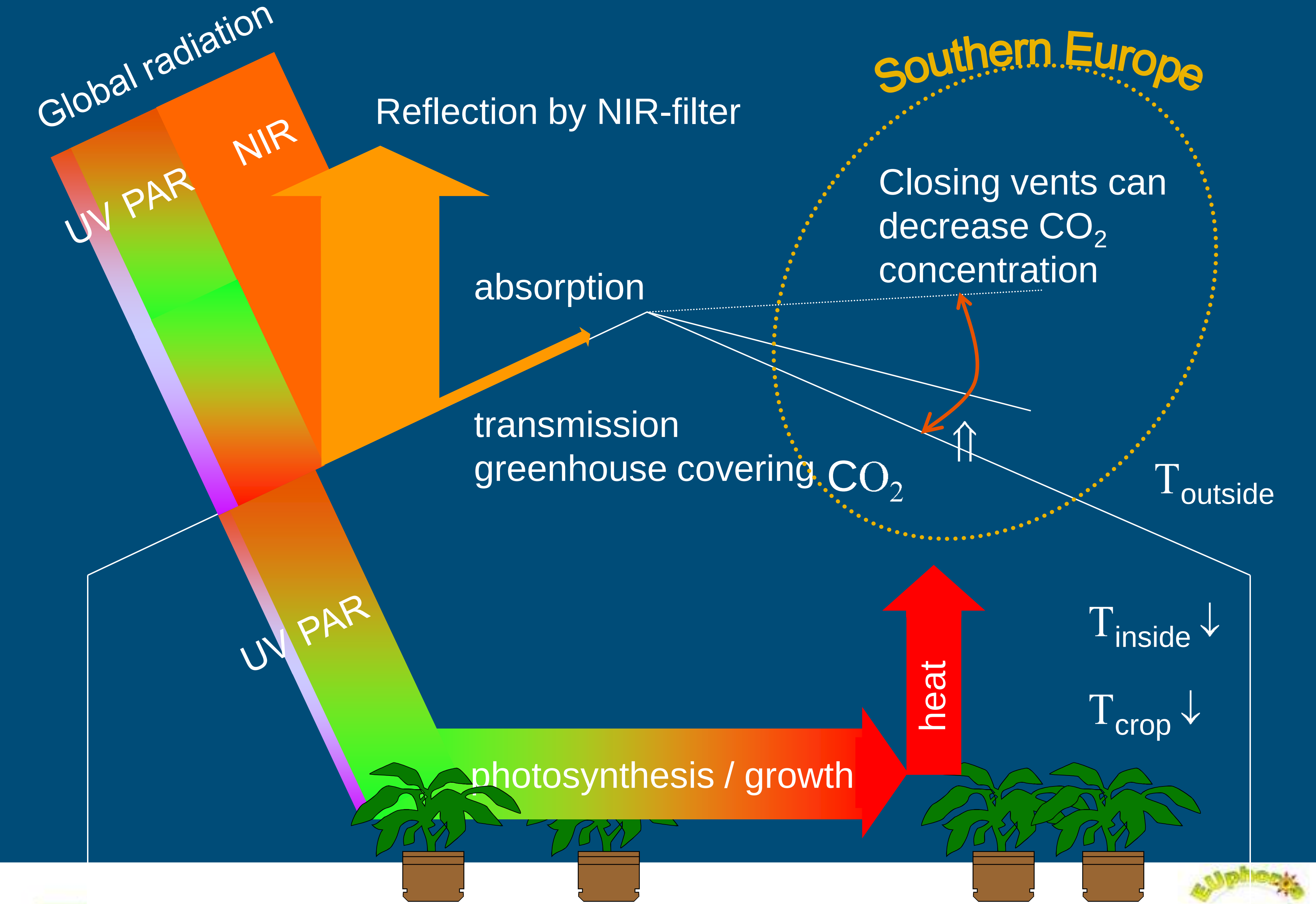

Sensitivity of
'all' plants = PAR 400-700nm

Sensitivity of
human eye
= visible light 380-780nm



# Heat input


Global radiation
UV
PAR
NIR
absorption
ventilation open
transmission
greenhouse covering
$CO_2$ ⇓
$T_{outside}$
heat
$T_{inside}$ ⇑
$T_{crop}$ ⇑
increasing temperature
photosynthesis / growth
UV
PAR

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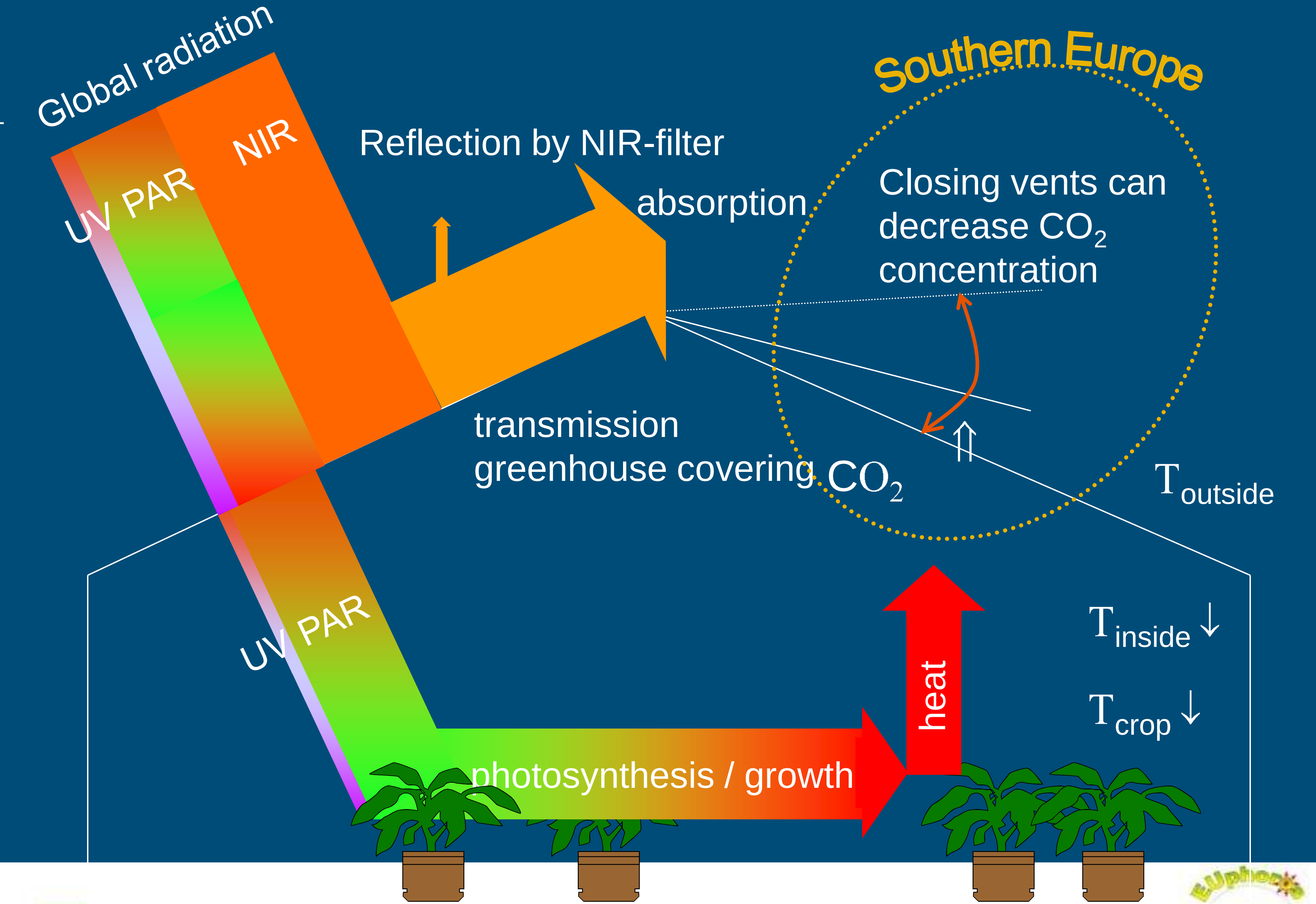
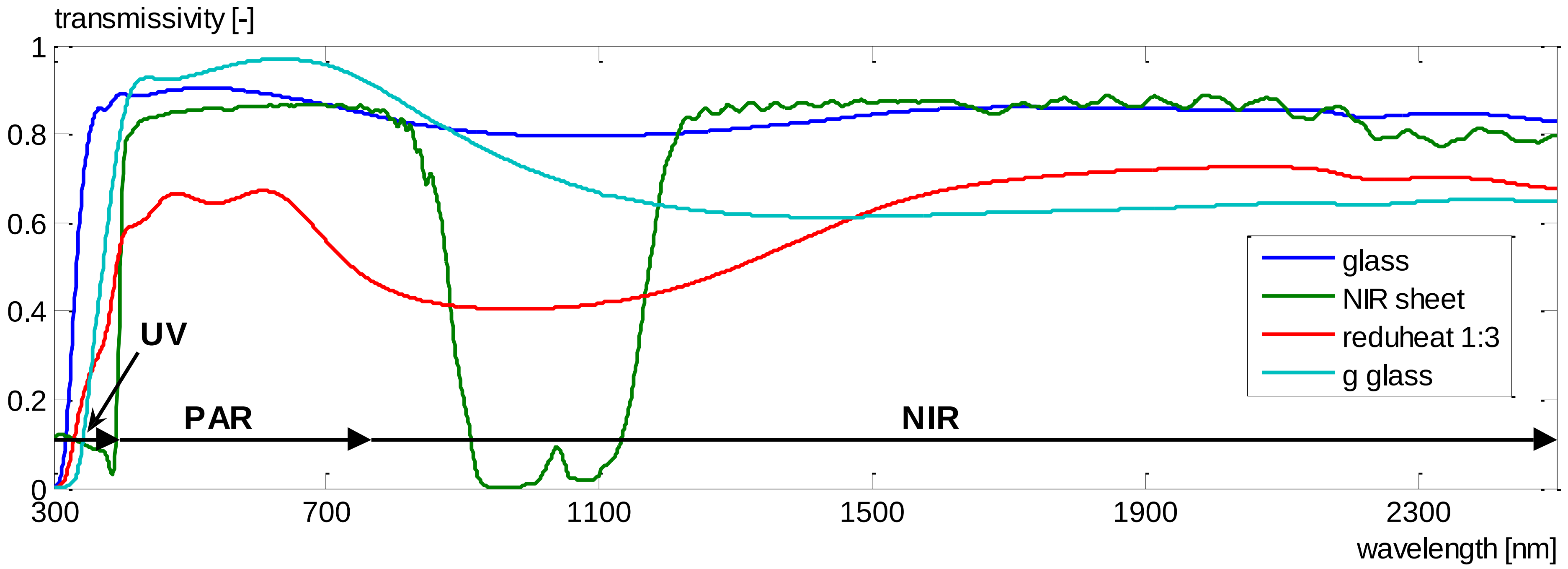
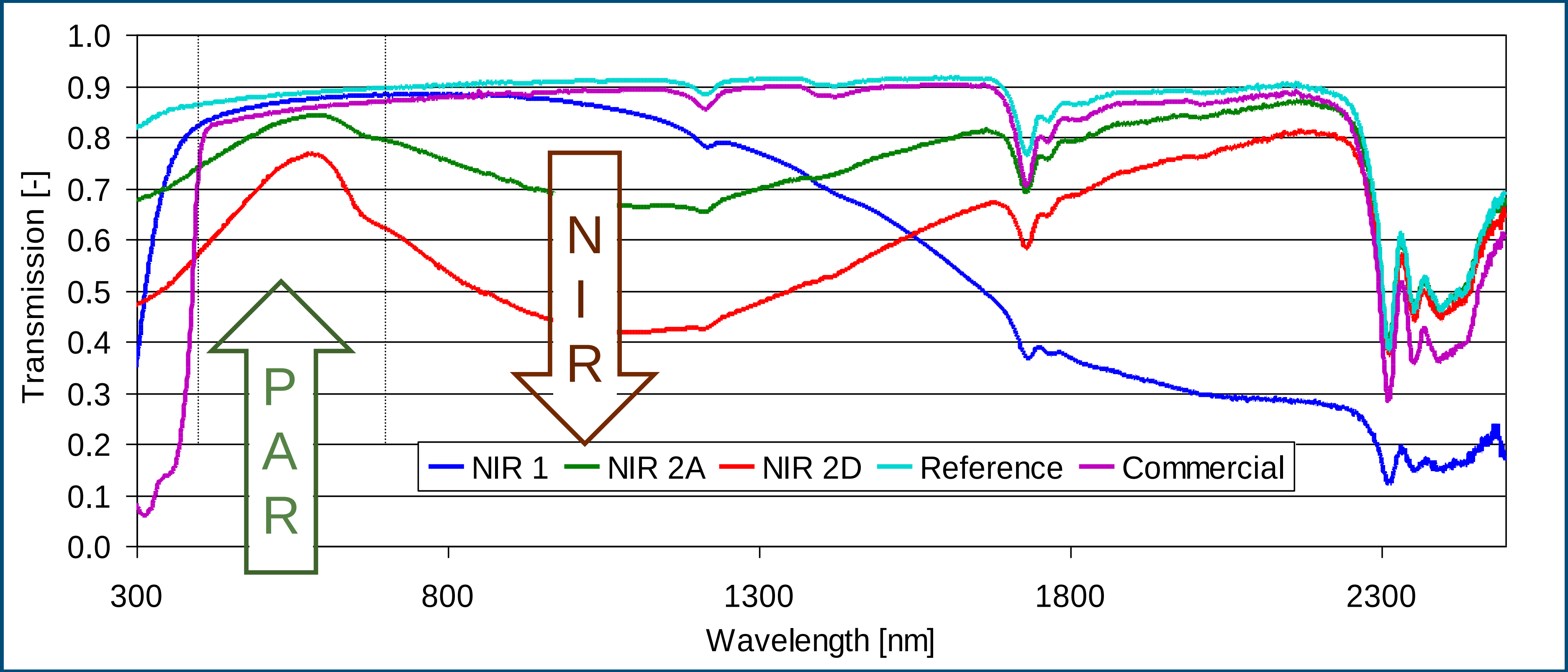

Southern Europe
Global radiation
UV PAR
NIR
Reflection by NIR-filter
absorption
Closing vents can decrease CO2 concentration
transmission
greenhouse covering
CO2
T outside
UV PAR
heat
T inside ↓
T crop ↓
photosynthesis / growth

# NIR-filtering materials

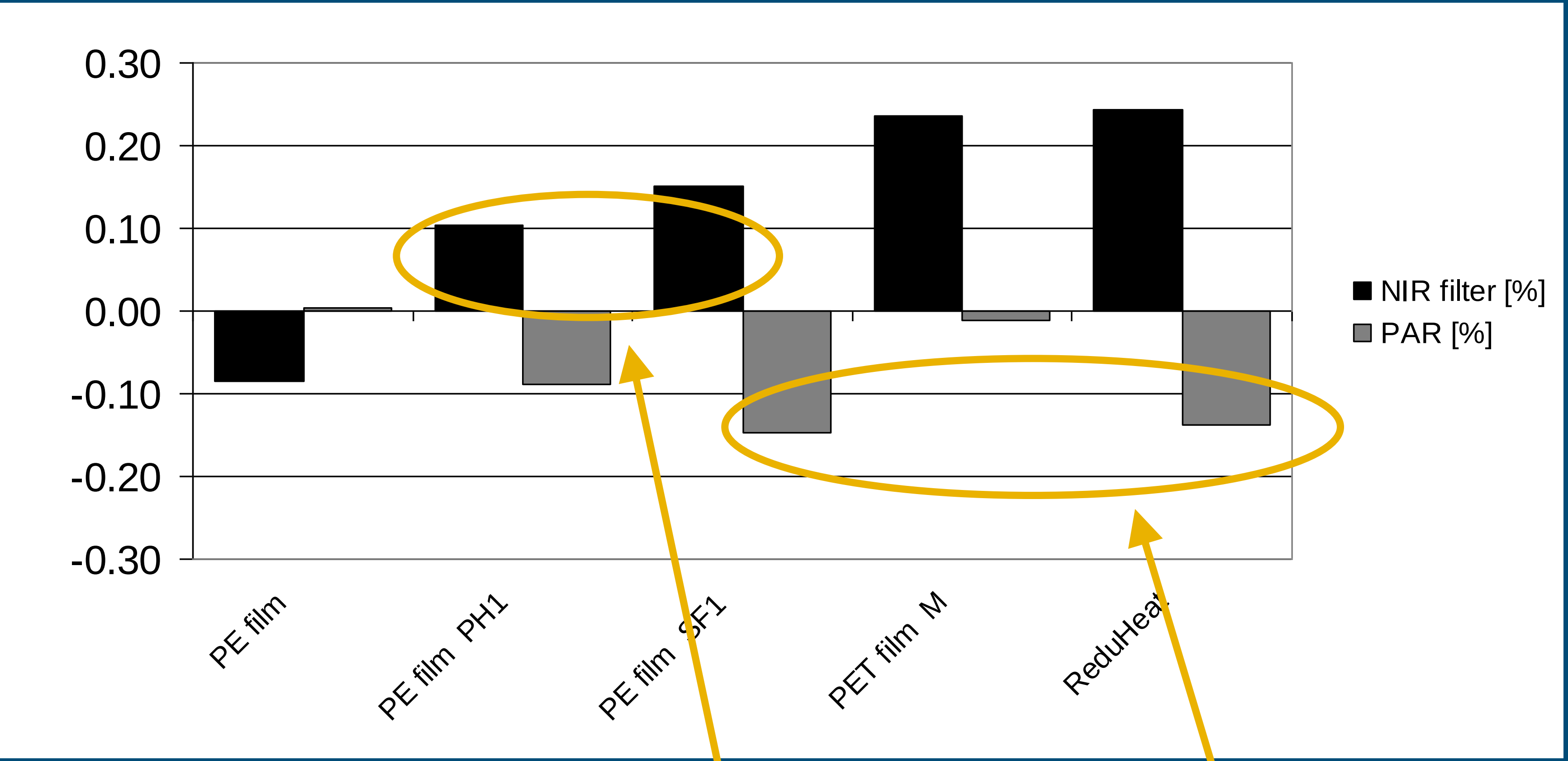


# Transmission of 5 plastic films




- NIR absorption up to 39% of NIR energy (NIR 2D)

# NIR-filtering materials

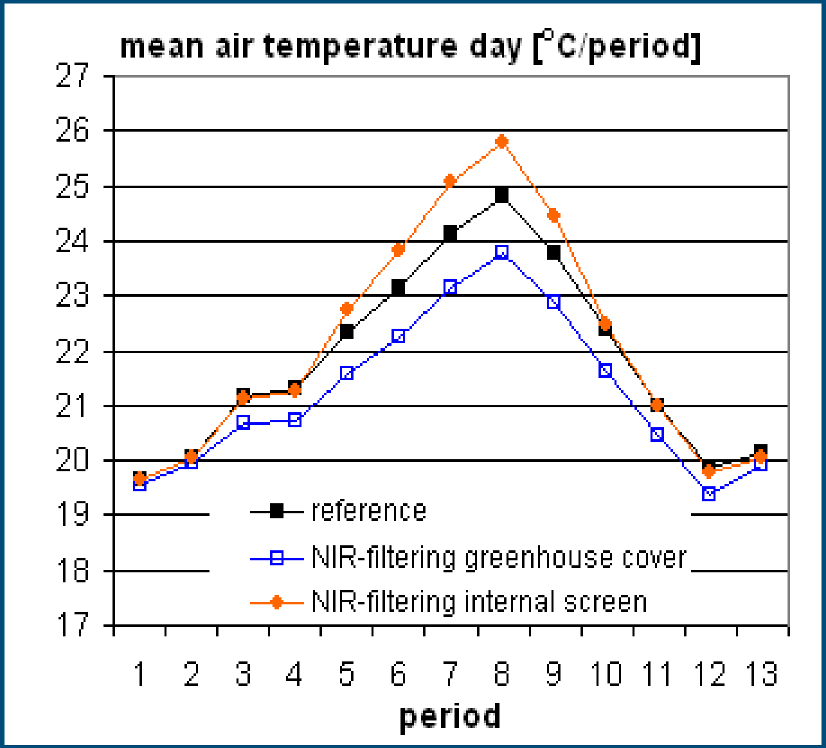


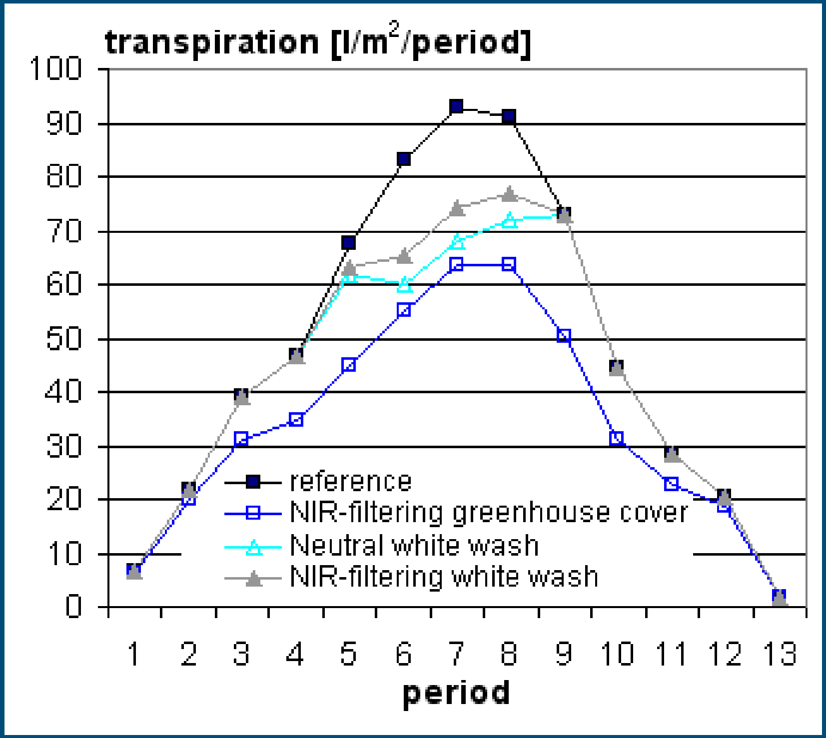

Low NIR-filtering

High PAR light losses

# Crop reaction (NIR Reflection CALCULATED)

Air temperature is less affected, crop temperature drops…

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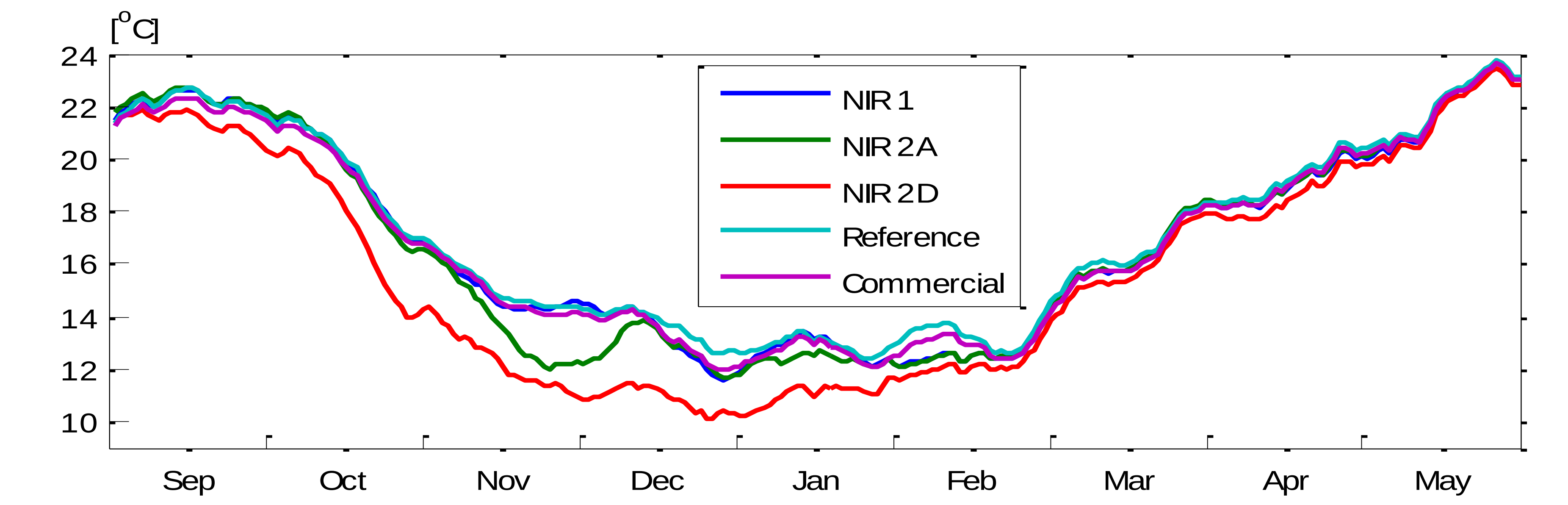
# effect on air temperature (NIR absorption calculated)




- In winter a larger fraction of the absorbed energy is released outside.

→ greenhouse temperature is lowered by the NIR-filter

# Experiment with absorber (Spain)

- $1200\ m^2$ greenhouses
  - Reference
  - NIR absorber

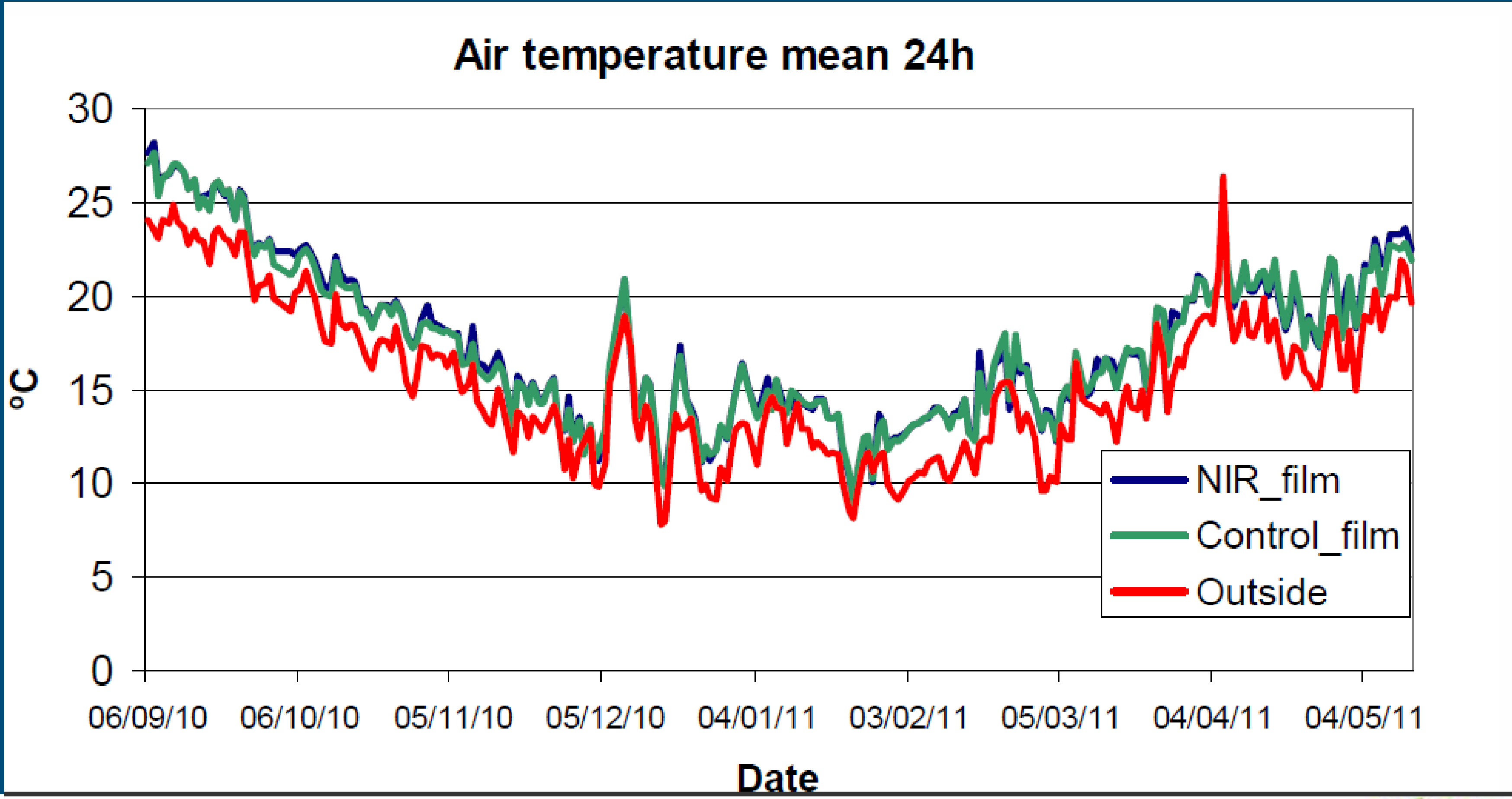
| Transmissivity | Reference | NIR absorber |
|---|---|---|
| PAR | 0.85 | 0.73 |
| NIR | 0.88 | 0.64 |

- 16 % reduction PAR
- 35 % reduction NIR

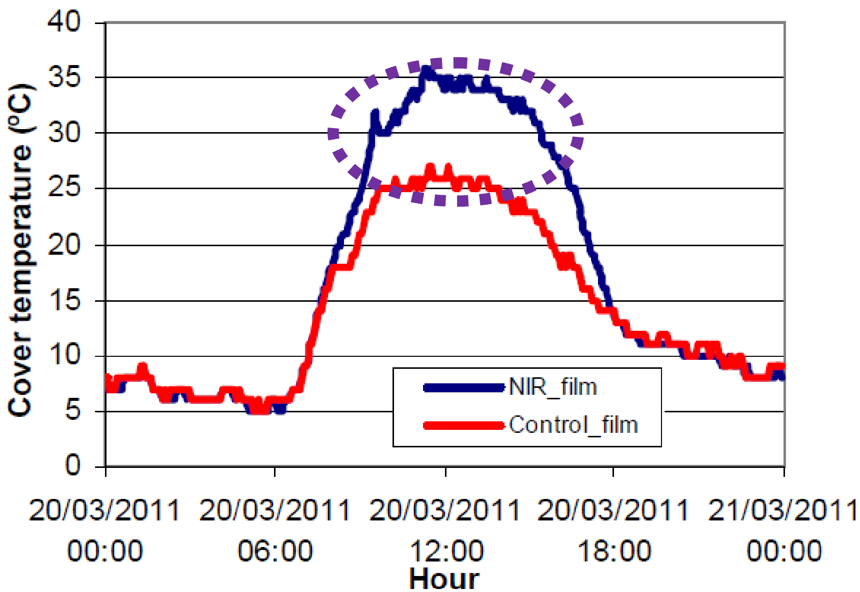
compared to reference

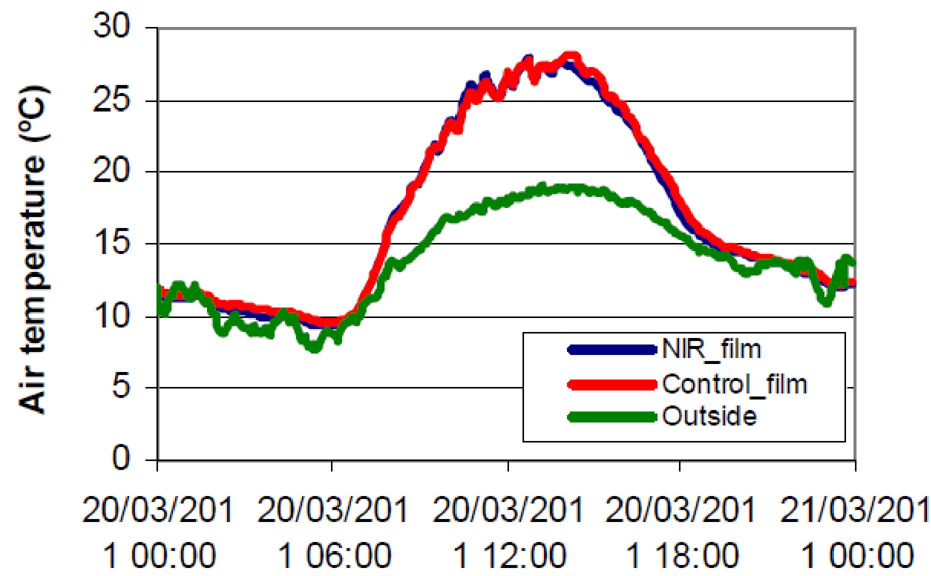
# Experiment with absorber (Spain)

## Small differences in temperature

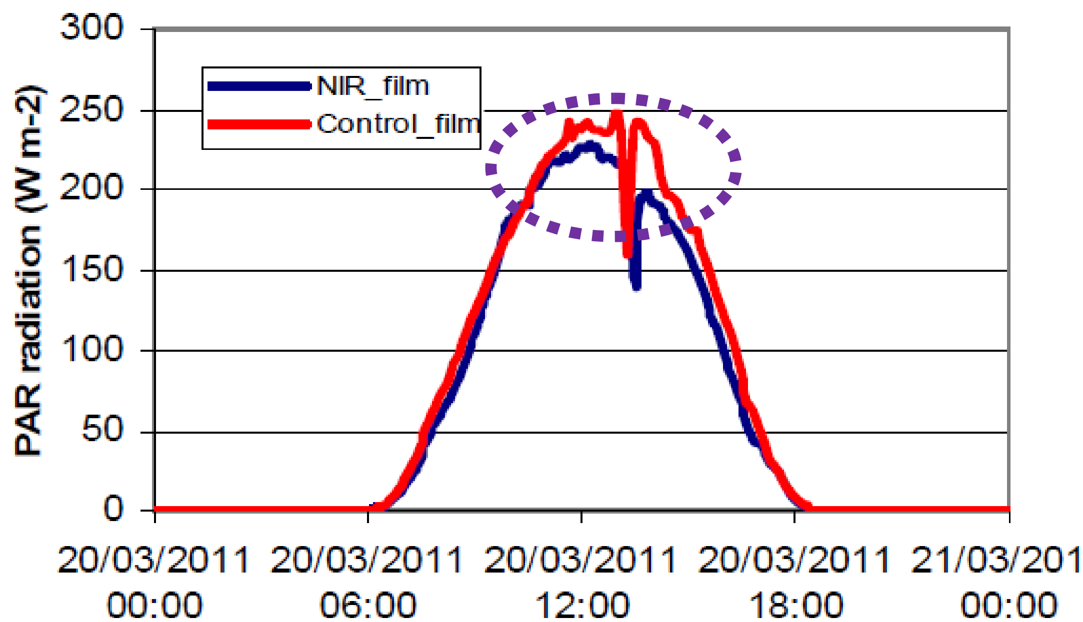


# Experiment with absorber (Spain)




Net energy effect about 0

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# Conclusions absorber (calculations and experiment)

- A year-round NIR filter can lower temperature in winter (reduced energy load of greenhouse).
- In summer sometimes even higher temperatures.
- Cover temperature increases up to very high levels.
- The combined effect of all spectral properties ($\tau$, $\alpha$, $\varepsilon$) needs to be considered.
- Reduction in PAR transmission will have effect on production (about 15 % production loss = about PAR loss)

# Conclusion reflection (Dutch experiment)

- Significant reduction of ventilation needs
  - Be aware of back fire in case of non $CO_2$ supply

- Reduction of transpiration reduces need for humidity control (energy saving)

- No effects found on crop production and quality (because no difference in PAR transmissivity)

- Improving of NIR-sheet required (NIR once inside the greenhouse is trapped by the cover)

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# NIR-filtering conclusions (general)

- In (unheated) greenhouses use of an (movable) NIR-filtering outside screen only in hot periods
- $CO_2$
- Increase WUE (reduction of energy load)
- Strait white wash decrease assimilation
- PAR transmissivity should not be affected
- Crop is a good reflector for NIR.
- Efficiency of reflection is limited by re-reflection.

# Questions?